UNDERSTANDING THE PERCEPTION OF GAZE VERSUS NON-GAZE STIMULI

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Table of Contents

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Abstract

The ability to follow and interpret the gaze of others is vital for communicating with, and sharing information with, those around us. Gaze allows us to access the focus of interest of others and share information about location and our surroundings in general (Marotta, Lupiáñez, Martella, & Casagrande, 2012). Due to the fact that we use gaze to aid our understanding and sometimes direct our attention to something attended to by others, it is plausible that our ability to respond to the gaze of others may be special in some way or that we may be better at following its direction than we would be at following a sign pointing a certain way (Friesen, Ristic, & Kingstone, 2004; Marotta et al., 2012; Marotta, Román-Caballero, & Lupianez, 2018).

While a number of studies suggest that gaze may differ from non-biologically relevant stimuli that do not carry social significance, other research found no evidence that responding to gaze differs from responding to non-gaze stimuli. These inconsistent results have led to the debate whether eye-gaze is special in some way due to its important role in social communication or whether differences in responses are as a result of some other factors.
In the present study we address these differing results. Specifically, we investigate in four experiments whether differences in the response patterns between the gaze and arrow conditions found in Marotta et al. (2018) could be caused by differences in the physical properties of the two types of stimuli rather than the nature of the stimuli. In Experiment 1 we aimed to replicate the experiment in Marotta et al. Participants saw two types of targets (a pair of human eyes in one block and two arrows in a different block). In both cases, the stimuli appeared on the left or the right of a central fixation cross and they pointed to either the left or the right. The task was to identify what direction the targets were indicating regardless of the side of the screen that they were presented on. The main results in Marotta et al. were replicated. Participants were faster when responding to the arrow targets than the

gaze targets. In addition, a significant congruency effect (response times and/or errors increase when the side that the stimuli were presented on and the direction that the stimuli indicate conflict with each other) was found in the arrow condition but not in the eye-gaze condition. Experiment 2 was identical to Experiment 1 except for the stimuli used. The gaze stimuli were replaced with infinity-like symbol stimuli. Participants continued to respond faster to arrows than symbols, and the congruency effect was again found when arrows were used but not when symbols were used. Experiments 3 and 4 compared responses to the gaze and infinity symbols directly, with the two types of stimuli presented in different blocks in Experiment 3 but within the same block in Experiment 4. When stimuli were presented randomly within the same block in Experiment 4, the same pattern of data was found between the gaze and infinity symbol trials, and there was no evidence of a congruency effect in either condition.

Overall, the results showed that when the targets were not physically alike, response patterns differed between the two types of stimuli. However, when the physical properties of the targets were similar, response patterns were also similar. These results provide evidence against the idea that we respond differently to gaze than we do to stimuli with no biological relevance to us. These results underscore the importance of controlling physical differences between stimuli when studying gaze processing. They also suggest that some previously reported findings in support of a special role of gaze in attracting attention may be caused by factors other than the nature of the stimuli being of biological significance.

The ability to follow and interpret the gaze of others is vital for communicating with, and sharing information with, those around us. Gaze allows us to access the focus of interest of others and share information about location and our surroundings in general (Marotta, Lupiáñez, Martella, & Casagrande, 2012). Due to the fact that we use gaze to aid our understanding and sometimes direct our attention to something attended to by others, it is plausible that our ability to respond to the gaze of others may be special in some way or that we may be better at following its direction than we would be at following a sign pointing a certain way (Friesen, Ristic, & Kingstone, 2004; Marotta et al., 2012; Marotta, Román-Caballero, & Lupianez, 2018).

A number of studies suggest that gaze may differ from non-biologically relevant stimuli that do not carry social significance. While some of these studies highlight our tendency to reflexively orient our attention to eye-gaze in a way that is distinct from how we orient our attention to biologically irrelevant or socially insignificant stimuli (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999), others focus on differences in response times (RTs) when comparing the two types of stimuli (Marotta et al., 2012; Marotta et al., 2018). For example, Friesen and Kingstone (1998) used schematic faces to investigate whether gaze shifts could produce automatic shifts of attention. Participants were presented with a line drawing (schematic) of a face looking left, right, or straight ahead on a computer screen. The task was to respond to a target letter (F or T) that could appear either on the left or on the right of the screen. The participants were informed that the gaze direction shown on the face was not predictive of where the target letter would appear. The results showed that when the cue-target stimulus-onset-asynchrony (SOA) was short (i.e., 105 ms or 300 ms) response times were faster when the face appeared to look in the same direction as the target compared with when the face looked at a different direction from the target. Importantly, when the cue-target SOA was long (i.e., 1005 ms), the cueing effect disappeared. These

results show that non-predictive gaze cues were able to elicit a reflexive attention shift to a peripheral location, and that the short-lived nature of the cueing effect is consistent with the idea that the attention shifts were reflexive and might involve covert attention. Thus, even with no apparent reason to follow the gaze of the face, participants still shifted their attention to the cued location, suggesting that this response is automatic. Based on these results, the authors suggest that we may have a specialised ability to respond to gaze direction.

Similarly, Langton and Bruce (1999) investigated whether social attention cues such as the direction of the head can have a reflexive influence on the allocation of attention. Participants were shown a pre-cue on a computer screen of a head that could be tilted up, down, left, or right. They were asked to indicate via a key press where a target appeared (targets could appear at any of the four locations indicated by the head). The first three experiments investigated whether an exogenous orienting response would be triggered by the orientation of the head serving as a pre-cue to the location of the target. Faster responses were produced in the cue condition (i.e., when the head was angled up, down, left, or right) than in the neutral condition (i.e., when the head was appeared to face forward) when the SOA between the cue and the target was short. The results showed that a reflexive orienting response was produced by the cue, indicating that the direction of the head was able to influence the detection times of targets in the peripheral. However, as the authors noted, it is unclear whether it was the position of the head, the direction of the gaze, or both that produced these results. To investigate whether the orienting effects seen in the previous experiments were due to signalling by the cues or were the result of some physical property that the cues had, the authors conducted Experiment 4, in which inverted faces were used as cues. Cueing effects were found when the head looked left or right, but not when it looked up or down. These results suggest that it is unlikely that it was solely the physical properties of the stimuli that were responsible for the cueing effects in the previous experiments.

Driver et al. (1999) also investigated whether orienting to the gaze of another person can occur automatically. Specifically, they asked whether shared attention would occur when a person has no incentive to follow the gaze of another person, and whether shared attention would occur even when it is detrimental for a person to orient their attention to match the gaze that they had seen moments prior. Participants saw a centrally located human face on a computer screen. The eyes on the face looked either left or right before a target letter (T or L) appeared on the left or the right of the screen. The task was to identify as rapidly as possible whether the target was the letter T or the letter L. As the direction of the face was spatially uninformative of where the target was to appear, there was no reason for participants to attend to the location indicated by the gaze. The results indicated that response times were shorter at the direction indicated by the face (cued location) than at the direction not indicated by the face (uncued location). This suggests that attention was involuntarily attracted to the location that the face was looking at. Furthermore, in a subsequent experiment, it was found that when the cue-target SOA was short (i.e., 300 ms), this cue validity effect persisted even when the target was four times more likely to appear at the uncued location. This latter result is important because it shows that the cueing effect was not affected by a significant change in event probability when the cue-target SOA was short. Participants were unable to override the need to look in the direction that the face was looking even when it was detrimental for them to do so.

Further support for gaze being unique due to its social significance lies in the difference in response times when participants are asked to respond to gaze versus other non-biologically relevant stimuli. When gaze is compared to arrows, responses to arrows are generally faster than responses to gaze (Friesen et al., 2004; Hietanen, Nummenmaa, Nyman, Parkkola, & Hämäläinen, 2006; Vlamings, Stauder, van Son, & Mottron, 2005). It is proposed that this pattern of data arises because we have learned that eyes provide us with

social information, and as a result, we spend more time looking at gaze compared to other objects because of its complexity and social significance (Marotta et al., 2018). If exploration of the images containing eye-gaze is due to its social significance, it makes sense that coding gaze stimuli can take longer than coding arrow stimuli. However, it needs to be pointed out that differences in response times may be due to differences in the physical properties of the stimuli, a point that we will discuss later.

Support for differences in reaction times between gaze and arrows being due to social significance has been found in studies that used participants with autism. Individuals with autism are often impaired when it comes to social interaction and communication (American Psychiatric Association, 2013). Vlamings et al. (2005) compared the pattern of responses between two groups of participants, one with autism and one without, and measured their reaction times responding to eye gaze stimuli vs arrows. The results show that responses were slower in the gaze condition compared to the arrow condition when the participants were typically developed individuals without autism. When the participants were individuals with autism, this difference was not found. These findings are consistent with the idea that eye gaze stimuli are social in nature since individuals who are known to be impaired in social attention (e.g., people with autism) do not appear to treat the two types of stimuli differently.

Senju and Johnson (2009) proposed that when we make eye-contact with another person, our brain may respond in a unique way. They coined the term the “eye-contact” effect to describe the phenomena that “perceived eye contact with another human face modulates certain aspects of the concurrent and/or immediately following cognitive processing” (p.127). In support of this, Senju, Hasegawa, and Tojo (2005) found that in a visual search task, participants were faster to detect direct gaze than averted gaze. Macrae, Hood, Milne, Rowe, and Mason (2002) found that relative to averted gaze, when targets displayed direct gaze, participants were quicker to discriminate the gender of the target face. These results support

the idea that we may be sensitive to the perception of "eye-contact". Neuroimaging studies further show that compared with averted gaze, perception of direct gaze (eye-contact) resulted in larger areas of activation in the social brain network (Georgescu et al., 2013; Kawashima et al., 1999; Pelphrey, Viola, & McCarthy, 2004). The "social brain network" refers to the areas of the brain that are commonly considered to be involved in social cognition (Crafta, 2015). These areas include the amygdala, the superior temporal sulcus (STS), inferior frontal gyrus (IFG), anterior cingulate cortex (ACC), medial prefrontal cortex (mPFC), and the anterior insula. Areas specifically activated by eye-contact are the anterior and posterior parts of the right STS region, the fusiform gyrus, the medial and orbitofrontal cortices, and the amygdala (Calder et al., 2002; Kawashima et al., 1999; Sato, Yoshikawa, Kochiyama, & Matsumura, 2004; Schilbach et al., 2006; Senju & Johnson, 2009; Wicker, Michel, Henaff, & Decety, 1998; Wicker, Perrett, Baron-Cohen, & Decety, 2003). If we are sensitive to eye-contact and eye-contact is able to affect activity in the social brain network, this would support the idea that eye-gaze may be special due to its social significance.

Baron-Cohen, Wheelwright, and Jolliffe (1997) highlighted the unique relationship we have with eye-gaze by developing a theory of "mentalizing". This refers to our ability to figure out what another person is feeling or intending to do (their state of mind) from their eye gaze. The idea is that humans can use the eye-gaze of another person to anticipate and explain the behaviour of others. It was suggested that we can interpret the intention of another person through observing and joining with their gaze. A glance to the left might be a communication that one wishes to move to the left and we are given access to this information by participating in what Baron-Cohen referred to as "joint attention". If eye-gaze can communicate intention, orienting our attention to where another is looking would be advantageous for us. It is beneficial to shift our attention to that location since that is where the next action will probably take place. Thus, it is possible that we have learned that joint

attention can lead to some kind of advantage or at least access to more information about another's intentions. Perhaps because of this knowledge, we automatically look in the same direction where other people are looking at, but we do not react in this way to other directional stimuli. If this is the case, it would further support the notion that we respond to gaze in a unique way.

However, there is also evidence in previous research that shows no difference in performance when participants respond to gaze or non-gaze stimuli. Downing, Dodds, and Bray (2004) compared the reaction times of participants identifying a target letter (T and L) when they viewed a face with eyes looking left or right to the reaction times of participants identifying a target letter (T and L) when viewing a face with a tongue extended laterally to the left or the right. When the direction of the tongue was a non-predictive cue, no difference was found between the two conditions. However, when the target was four times more likely to appear at the uncued location, the tongue cues were unable to produce automatic shifts of attention in the same way as the gaze cues.

Kuhn and Benson (2007) investigated whether arrows and eye-gaze stimuli differ in affecting participants' ability to execute voluntary saccades. On each trial, participants made a saccade to a target on the left or right side of a display. They saw a centrally located cue of either a face or a horizontal line with black diamonds on each end. The cues were flanked by two black circles that would change to red or green and at the same time the cue would indicate either left or right. Participants were pre-instructed to look a certain way depending on what colour the circles would turn. Half of the trials were congruent (cue indicates left and participant sees a colour that tells them to look to the left) and half of the trials were incongruent (cue indicates left and participant sees a colour that tells them to look to the right). Although participants took longer and made more errors in the incongruent conditions rather than the congruent conditions, there was no significant effect of cue type or cue by

congruency interaction. In other words, the arrow cue and the eye-gaze cue caused the same amount of interference in the incongruent condition compared with the congruent condition. These results are contrary to those of previous research reported in Ricciardelli, Bricolo, Aglioti, and Chelazzi (2002) where they found that only eye-gaze stimuli were able to produce automatic gaze following. Instead, the results in Kuhn and Benson showed that eye-gaze and arrows were both able to effectively elicit saccades in a direction that was not beneficial to the completion of the task. This suggests that eye-gaze is not a "special" type of stimuli due to its biological relevance in this case.

Contrasting the evidence supporting the idea that an "eye-contact effect" may be modulating cognitive processing that follows, Conty, Tijus, Hugueville, Coelho, and George (2006) show that different results can be obtained when the images used do not include the entire face. They investigated the impact of eye-contact on response times using images that only included the eyes and the bridge of the nose. Participants were given a visual search task and the task was to search for a specific gaze orientation (averted or direct gaze in different blocks) and indicate if that gaze orientation was present in the display amongst distractors of the opposite orientation (e.g. participants were to locate direct gaze amongst averted gaze distractors or vice versa). Results showed that direct gaze was detected faster than averted gaze, but this was dependent on the head deviation (angle) shown by the bridge of the nose. Participants were only faster at detecting direct gaze among distractors when the head angle was deviated. Results also showed that the detection of averted gaze was more influenced by head orientation than the detection of direct gaze. These results suggest that schematic frontally viewed gaze stimuli may not be affected by the eye contact effect as it would seem that for the eye-contact effect to manifest, the image must show the head at a deviated angle. This suggests that the "eye-contact effect" may not apply to research that uses eye-gaze stimuli that does not also include a visual representation of the orientation of the head.

As demonstrated above, in the existing literature there is a tendency to only include the eye stimuli in an experiment or if multiple types of stimuli are used, they are often in no way similar to the eye-gaze stimuli in regard to their physical properties. A common choice is to compare eye images with arrows. What is missing in the literature is a comparison of eye-gaze stimuli with stimuli that are similar in colour, shape, and size. If we are to make claims about gaze being special in some way, it seems reasonable that we should try to use physically similar stimuli.

For instance, Marotta et al. (2018) recently conducted an experiment in which participants saw a pair of arrows pointing left or right or a pair of eyes looking left or right. The arrows and the eye-gaze stimuli could be on the left or the right side of the screen. Thus, the location of the target was either congruent (e.g., the direction indicated by the target was left and the target was presented on the left side of the screen), or incongruent (e.g., the direction indicated by the target was left and the target was presented on the right side of the screen). The task was to identify what direction the target was indicating, regardless of its location on the screen. Their results showed that the pattern of data differed between the arrows and the eye-gaze stimuli. In the arrow condition, RTs were faster when the direction pointed by the arrow was congruent with its location compared with when the two were incongruent. This is a typical example of a spatial Stroop effect, which indicates that the location of a stimulus influences response selection. However, the eye-gaze condition produced the opposite pattern. Faster RTs were found when the direction of the eye-gaze was incongruent with its location than when they were congruent. Marotta et al. interpreted this pattern of data as the result of the gaze stimuli being special in social significance and complexity, which in turn induced more exploration of the stimuli and the participant's attempt to discern the "intention" of the direction of the gaze stimuli.

An important aspect of the results produced by Marotta et al. (2018) is the difference in the overall reaction times between the arrows and the eye-gaze stimuli. Instead of being caused by some kind of "special" response to biological stimuli due to an affinity for participating in shared gaze, the results may be produced by the difference in the size of the attentional window required by the two types of stimuli. Previous research has shown that it takes longer to respond to the target when a task requires a narrow attentional focus compared with when a task requires a relatively broad attentional focus (Chen & Cave, 2016). In Marotta et al.'s experiment, in the arrow condition, the arrows, which were black, were presented directly against the grey background. The locations of the arrow heads were quite obvious, and the direction indicated by the arrows was easy to perceive. In contrast, in the eye-gaze condition, the direction indicated by the gaze was much harder to perceive as the directional information was provided by a much smaller area of the image (in this case the pupil). In addition, the eye-gaze stimuli were shown against a peach coloured surround, and this made the direction of the gaze difficult to perceive. Consequently, while a narrow attentional focus was required to perform the task in the gaze condition, a relatively broad focus was sufficient in the arrow condition.

The difference in the attentional focus requirement would result in faster RTs in the arrow condition than in the eye-gaze condition, and this was what was found in Marotta et al. (2018). The broader attentional focus in the arrow condition would also lead to better encoding of the location of the target on the screen, resulting in the spatial congruency effect. It is unclear why a reversed congruency effect was found in the eye-gaze condition.

In the current study, we test the hypothesis that the pattern of data observed in Marotta et al. (2018) may not be caused by the inherent differences between the two types of stimuli (i.e., eye-gaze vs arrows), with the eye-gaze stimuli carrying information about social cognition and the arrow stimuli not conveying this kind of information. Instead, we

hypothesise that the different pattern of data arises due to the difficulty in determining the direction of the gaze. When the stimuli and procedure used in the original study are used in the present study, we expect that RTs in the gaze condition will be slower than those in the arrow condition due to the time it takes to narrow the attentional focus in the gaze condition as it is harder to know the direction the eyes are oriented in that condition. We further expect that non-gaze stimuli that require narrow attentional zoom (e.g., infinity symbols) will show the same pattern of data as the gaze. If our predictions are correct, the results will be consistent with the proposal that the visual system has a general mechanism that processes both socially important and not-so-important stimuli (Santiesteban, Catmur, Hopkins, Bird, & Heyes, 2014).

The present study consists of four experiments. Experiment 1 served as a baseline experiment. The goal was to replicate Marotta et al. (2018). Arrow and eye-gaze images were used as the targets. They were pointed to the left or to the right and were shown on the left or right side of the screen. The task was to identify whether the target was pointing or looking to the left or the right as quickly and as accurately as possible regardless of the side of the screen that they were presented on. The results were largely consistent with those in Marotta et al.'s study. Experiment 2 replaced gaze stimuli with infinity symbols and found the same pattern of data as that found in Experiment 1. Experiments 3 and 4 compared responses to gaze and infinity symbols directly, with the two types of stimuli presented in different blocks in Experiment 3 but within the same block in Experiment 4. Taken together, there was no evidence that the attentional system treats gaze differently from non-biologically relevant stimuli in the current paradigm.

Experiment 1

Experiment 1 was modelled after Marotta et al. (2018).[1] Participants were shown either a pair of eyes or a pair of arrows and their task was to determine which direction the eyes or arrows were indicating, regardless of what side of the screen the image was presented on. It was expected that the results would be similar to those of Marotta et al. (2018) in which faster RTs were found in the eye-gaze condition than in the arrow condition, and the pattern of the congruency effect differed between the two conditions. If this pattern of data was observed, the experiment would serve as a baseline against which the results of subsequent experiments would be compared.

Method

Participants. Forty undergraduate students were recruited from the participant pool of the University of Canterbury Psychology Department in exchange for course credit. The mean age was 20.7 years (17 - 41 years). Participants were ignorant of the purpose of the experiment. The sample size was chosen based on the original experiment by Marotta et al. (2018), which had a sample size of 36, and on the result of a power analysis with G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009). The most important finding in Marotta et al. was the stimulus type by congruency interaction, which had a large effect size with $\eta_p^2 = .54$. With the same effect size, and with $\alpha = 0.5$ and 80% power, the recommended sample size from the G*Power analysis was 6. The sample size chosen for each experiment reported here was 40, which should have sufficient power to replicate the original results.

Apparatus and Stimuli. The experiment presentation and data collection were performed on a Windows computer running E-Prime 2.0 software at a resolution of 1680 x 1050 pixels with a refresh rate of 60Hz. Participants were individually tested in two dimly lit rooms and were seated in approximately 60cm from the computer screen.

The stimuli were presented against a black background. Each trial consisted of a fixation followed by a target display consisting of either a pair of eyes or arrows looking/pointing to the left or to the right (see Figure 1). The fixation was a white cross subtending a visual angle of 0.5°, and it was presented at the centre of the display. The target stimuli consisted of a display of two full-colour human eyes in the gaze condition or two black arrows in the eye condition, presented centred on a grey (RGB = 209, 210, 211) rectangle (6.2° x 10.5°). The overall size of the stimuli was the same in each of the two conditions, both measured 0.76° in height and 2.38° in width. For the gaze condition, the eye stimuli were images of real-life eyes looking either to the left or to the right, each contained within an oval of 0.95° in width and 0.76° in height. Each eye image included a portion of flesh that surrounded the eye. The eye, excluding the flesh surround, was 0.57° in width and 0.38° in height. The distance between the centres of each eye was 1.62°. The spatial separation between the centre of the eye image and the fixation cross was 4.10°. For the arrow condition, two black arrowheads pointed either to the left or to the right. Each arrowhead was 0.86° in width and 0.86° in height. The separation between the two arrows was 1.05°. In both conditions the distance from the centre of the image to the centre of the fixation cross was 4.9°, on either the left or the right side.

Design. The experiment used a 2 (stimuli type: eyes vs arrows) x 2 (congruency: congruent vs incongruent) repeated-measures design. Whereas stimulus type was manipulated between sessions, congruency was varied within a block. Each participant completed two sessions, with each session consisting of 16 practice trials followed by two experimental blocks of 64 trials per block, separated by a break period. Both the location and direction of the target were randomised and with equal proportion within each block. The order of the session was counterbalanced across participants.

Procedure. Each trial started with a fixation cross presented centrally for 1,000 ms. Following this display, either a pair of arrows or two eyes that indicated either left or right were presented either right or left of the fixation cross (see Figure 1). Targets could be congruent with their location (e.g. eyes or arrows are presented on the right side of the screen and are pointing to the right), or incongruent with their location (e.g. eyes or arrows are presented on the right side of the screen and are pointing to the left). Participants pressed the "Z" key with their left index finger or the "M" key with their right index finger to indicate the direction the target stimuli were pointing to. No feedback was provided during the experiment. Targets were terminated upon response or after 2,000ms have passed, whichever appeared first. The entire experiment took about 30 minutes to complete.

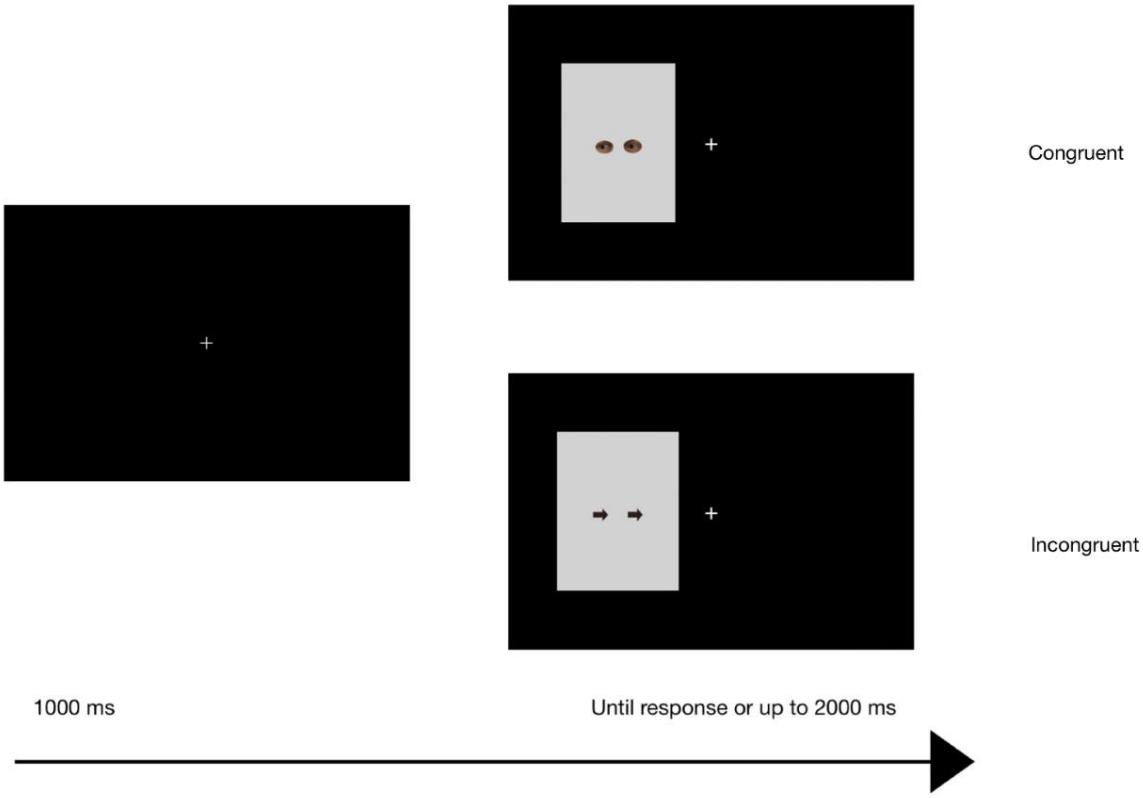


Figure 1. *Experiment 1. Schematic diagram of sequence of trials for the gaze and arrow target trials. In the congruent trial, the location of the target on the screen was the same as the direction indicated by the target. In the incongruent trial, the location of the target on the screen was opposite of the direction indicated by the target.*

Results and Discussion

All participants' data that exceeded 25% were removed from analyses. One participant's data were not included in the analyses below due to high error rates. To better compare our results with those of Marotta et al. (2018), we treated the data in the same way as they did: RTs faster than 200 ms or slower than 1,300 ms were excluded from the analyses. This resulted in the exclusion of 2.5% of the data. Means RTs and mean error are presented in Table 1.

Table 1. *Mean reaction times (in milliseconds), standard deviations (SDs), and percentages of mean error (%Err) for each condition in Experiment 1.*

	Gaze		Arrow		Gaze		Arrow	
Trial Type	RT	SD	RT	SD	%Err	SD	%Err	SD
Congruent	608	85	592	82	2.3	3.4	2.4	3.3
Incongruent	593	81	533	84	4.2	4.6	3.9	3.8

A 2 (stimuli type) x 2 (congruency) repeated measures analysis of variance (ANOVA) was performed on mean RTs. There was a significant main effect of stimuli type, $F(1, 38) = 78.70$, $MSe = 2370$, $p < .001$, $\eta p^2 = .67$. RTs were faster when participants were presented with the arrow stimuli (531ms) than when they were presented with the gaze stimuli (600ms). There was also a significant interaction between stimuli type and congruency, $F(1, 38) = 13.28$, $MSe = 3353$, $p < .001$, $\eta p^2 = .26$. In the gaze condition, there was a reverse congruency effect, with RTs significantly faster in the incongruent trials (593 ms) than in the congruent condition (608 ms). In the arrow condition, no difference was found between the congruent trials (529 ms) and the incongruent trials (533 ms). The main effect of spatial congruency was not significant, $F(1, 38) = 1.86$, $MSe = 1031$, $p = .18$, . $\eta p^2 = 0.05$.

A similar ANOVA was conducted on the error rates. A significant effect of congruency was found, $F(1, 38) = 12.93$, $MSe = 8.42$, $p < .001$, $\eta p^2 = .25$. Error rates were higher in the incongruent conditions (4.0%) than in the congruent conditions (2.4%). The main effect of stimulus type was not significant, $F(1, 38) = 0.05$, $MSe = 9.62$, $p = .83$, $\eta p^2 = .0$. The interaction between stimulus type and congruency was also not significant, $F(1, 38) = 0.30$, $MSe = 5.39$, $p = .59$, $\eta p^2 = 0.01$.

Importantly, there was a speed-accuracy trade-off in the gaze trials. Whereas the participants were faster in the incongruent trials (593 ms) than in the congruent trials (608 ms), they made more errors in the former than in the latter (4.2% and 2.3%, respectively). In response to this, adjusted RTs (AdjRTs) were calculated (AdjRT = RT/Proportion Correct)

for each participant. As AdjRT takes into account both speed and accuracy, it is a sensitive measure for processing efficiency (Chambers, Stokes, & Mattingley, 2004; Townsend & Ashby, 1983), and a more suitable measure here. The AdjRT data are shown in Figure 2.

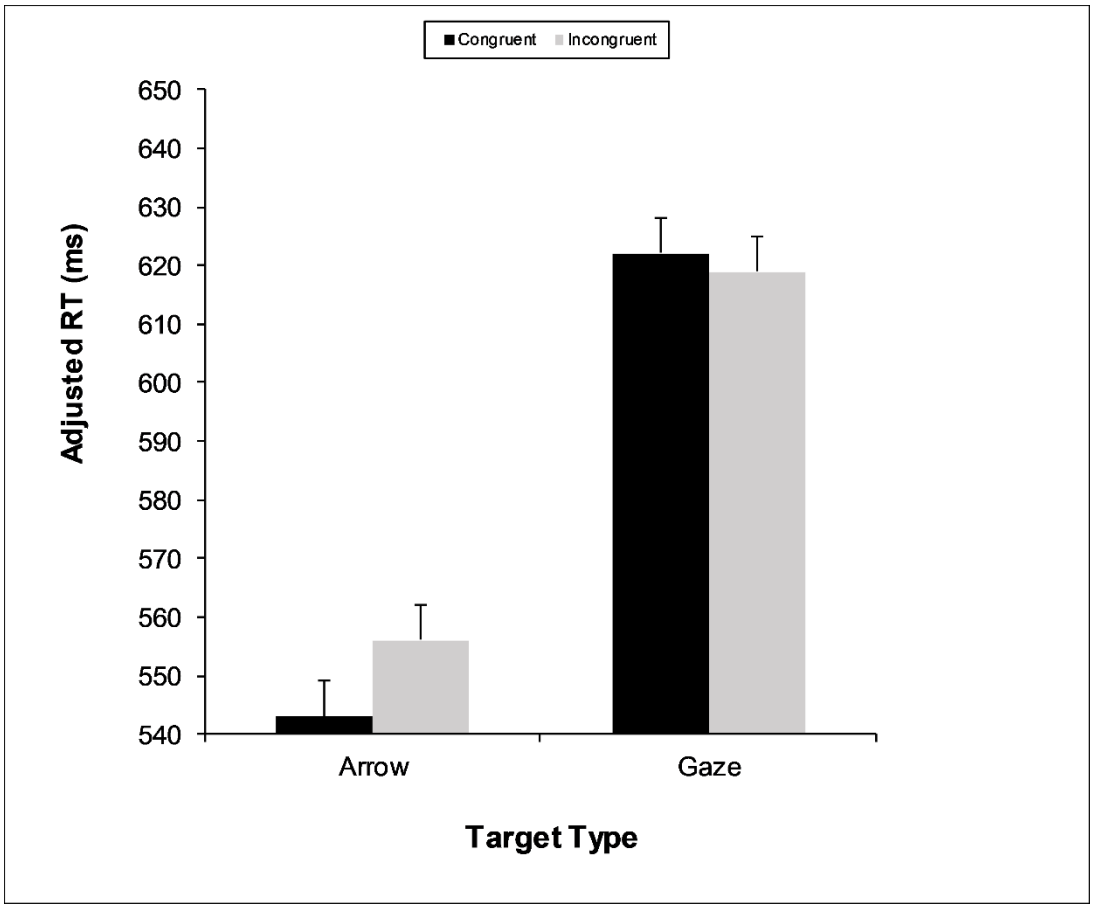


Figure 2. *Results from Experiment 1. The error bars show the within-subjects standard errors of the mean.*

Repeated measures ANOVA was conducted on the AdjRT data. A significant effect of stimuli type was found, $F(1, 38) = 50.16$, $MSe = 3991$, $p < .001$, $\eta_p^2 = .57$. AdjRTs were faster when participants were presented with arrow stimuli (549 ms) than with gaze stimuli (621 ms). The main effect of congruency was not significant, $F(1, 38) = 1.08$, $MSe = 1029$, $p = .30$, $\eta_p^2 = .0.03$. This indicates that there are negligible differences between the congruent trials (582 ms) and the incongruent trials (588 ms). The interaction between stimuli type and congruency was marginally significant, $F(1,38) = 3.90$, $MSe = 659$, $p = 0.06$, $\eta_p^2 = 0.09$.

Subsequent *t* tests compared RTs in the congruent and incongruent conditions. There was a significant difference in the RTs between the congruent arrow trials (543 ms), and the incongruent arrow trials (556 ms), $t(38) = 2.37$, $p = .02$, $d = 0.15$. This congruency effect was not present in the gaze trials (622 ms in the congruent condition vs. 620 ms in the incongruent condition), $t(38) = .38$, $p = .71$, $d = 0.04$.

Experiment 1 produced results that were largely consistent with those reported by Marotta et al. (2018). In line with their results, participants in the current experiment were faster at responding to arrow targets when compared with gaze targets. This indicates that the perception of directional information is more difficult when gaze targets are used than when arrow targets are used. The results also showed differences in patterns of data between the two target types. There was an effect of congruency when arrow targets were used but not when gaze targets were used. This indicates that spatial information produced by each type of stimuli did not produce the same amount of interference when it came to response selection. Simply, participants were not affected by congruency in the gaze trials. In Marotta et al., a reversed congruency effect was found in RTs in the gaze condition. When AdjRTs were used, we did not find any effects of congruency whether it be positive or negative. The reason for this is currently unclear and will be discussed further in the general discussion.

Marotta et al. (2018) attributed the differences between the arrow and gaze trials to a difference in the nature of the stimulus. However, it is also possible that the results were caused by the gaze stimuli being more difficult to perceive. Experiment 2 investigated this possibility by using stimuli that have similar properties to the gaze stimuli but do not evoke the image of eyes. This will allow us to investigate whether it is gaze stimuli in particular that participants are reacting differently to (when compared to stimuli with no biological significance such as arrows), or whether it is simply the physical properties of the stimuli (size, shape, colour), that cause them to be responded to differently. It is important to make

this distinction as it is unclear whether the differences in response patterns are due to differences in types of stimulus (eye stimuli are biologically relevant to us), or whether the differences are due to the ability to perceive the stimuli (with gaze being more difficult to perceive).

Experiment 2

Experiment 2 replaced gaze targets with symbol targets that were similar in shape, size, and colour in order to investigate whether participants would produce a similar pattern of data to that of the gaze condition in Experiment 1. Symbols have no biological relevance to us and are not used in social interactions. Therefore, if Experiment 2 produces data patterns similar to Experiment 1, it would be unlikely that the results in Experiment 1 were due to gaze being special in some way when compared to arrows. If gaze really is special due to its social significance, how we react to gaze stimuli should differ from how we react to stimuli that is not biological in nature and is of a similar size and colour such as symbols.

Method

Experiment 2 was the same as Experiment 1 with the exception of the stimuli used. The display consisted of a pair of arrows for half of the trials (the same as those used in Experiment 1) and a pair of infinity symbols for the other half.[2] Each infinity symbol, which subtended 0.38° in height and 1.15° in width, was surrounded by a rectangle (filled with a colour taken from the flesh surround of the gaze stimuli) that measured 0.86°in height and 1.15° in width.

The infinity symbol consisted of a darker part and a lighter part. The task was to identify whether the darker part was on the left or the right of the lighter part of the image. Participants pressed the “Z” key with their left index finger or the “M” key with their right index finger to indicate the direction the target stimuli were pointing to (See Figure 3). As

before, Experiment 2 consisted of 16 practice trials and 2 blocks of 64 experimental trials, separated by a break period. The location and direction of the target were randomised within each block. Participants were asked to respond as quickly and accurately as possible.

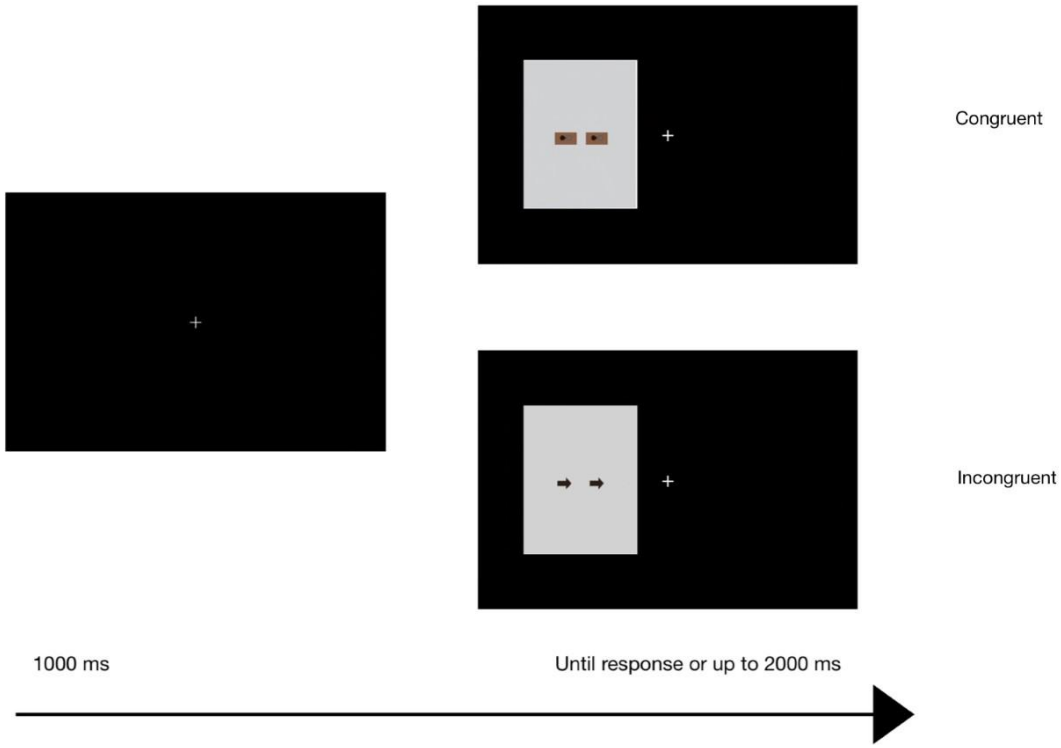


Figure 3. *Experiment 2. Schematic diagram of sequence of trials for the symbol and arrow target trials.*

Results and Discussion

To be consistent with Experiment 1, we treated the data in the same way in Experiment 2 as in Experiment 1 by using the same exclusion criteria and AdjRTs. (See Table A1 in the Appendix for the mean RTs and error rates). This would allow us to make a direct comparison between the two data sets. Two participants' data were excluded due to high error rates. A third participant's data was also excluded due to high AdjRT data, which exceeded 6 standard deviations above the mean of the remaining participants' data. The results are in Figure 4.

Repeated-measures ANOVA was conducted on the mean AdjRTs (Figure 4). As in Experiment 1, a significant effect of stimuli type was found, $F(1, 36) = 83.78$, $MSe = 2362$, $p < .001$, $\eta_p^2 = .70$. RTs were faster when participants were presented with arrow stimuli (560 ms) than when they were presented with symbol stimuli (633 ms). A significant effect of congruency was also found, with faster responses in the congruent condition (588 ms) than in the incongruent condition (604 ms), $F(1,36) = 5.54$, $MSe = 1783$, $p = .02$, $\eta_p^2 = 0.13$. As in Experiment 1, the interaction between stimuli type and congruency was marginally significant, $F(1,36) = 3.11$, $MSe = 928$, $p = .09$, $\eta_p^2 = 0.08$. Once again, *t* tests for dependent samples were conducted to compare RTs in congruent and incongruent conditions. There was a significant congruency effect in the arrow trials between the congruent condition (547 ms) and the incongruent condition (572 ms), $t(36) = 3.71$, $p < 0.01$, $d = .61$. This congruency effect was not present in the symbol trials (629 ms in the congruent condition vs. 637 ms in the incongruent condition), $t(36) = 0.75$. $p = 0.46$, $d = 0.13$.

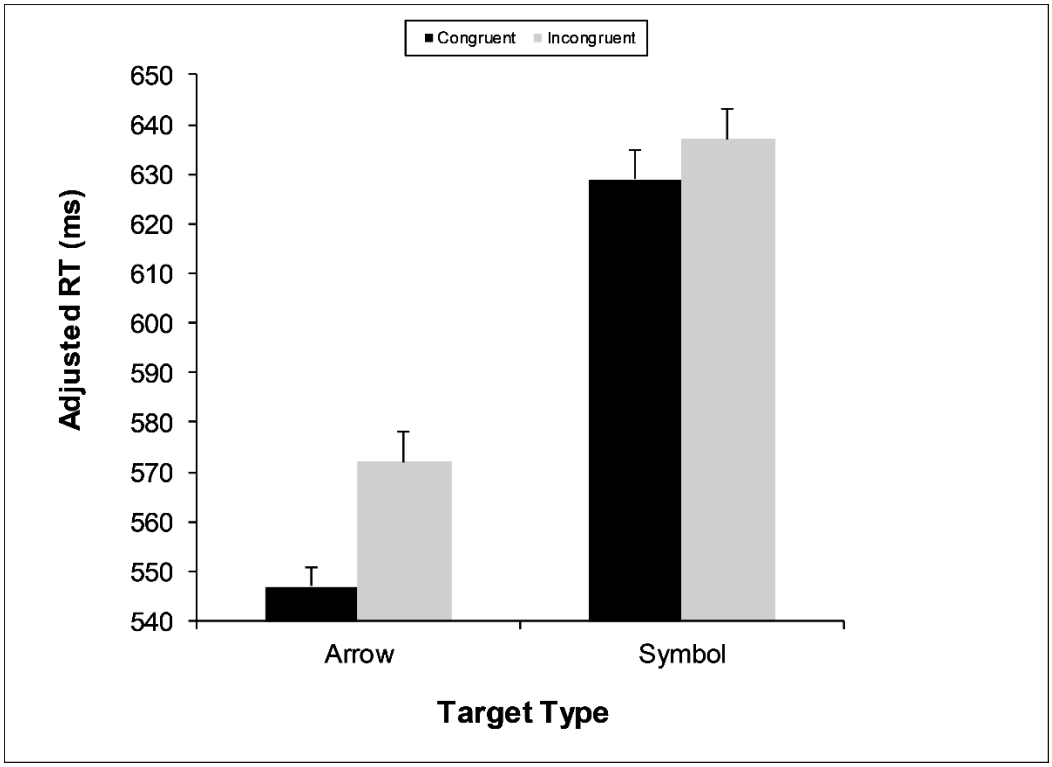


Figure 4. *Results from Experiment 2. Mean AdjRTs in milliseconds for each target type in each congruency condition. The error bars show the within-subjects standard error of the mean.*

The results of Experiment 2 are similar to those of Experiment 1. Participants continued to respond faster in the arrow trials, even when the gaze stimuli were replaced with stimuli that had similar physical properties but no biological significance (i.e., symbols). Once again, we saw an effect of congruency in the arrow trials but not in the symbol trials. These results are inconsistent with the idea that the pattern of data in Experiment 1 was the result of gaze being of social significance or biological relevance.

There may be another explanation for the absence of the congruency effect in the gaze and symbol trials. Arrows carry their directional information in the entire image. It is easy to see which way an arrow is pointing at a glance. Where the directional information lies in stimuli like eyes or symbols, however, is not so easy to perceive. This is indicated by the longer response times in the symbol condition than in the arrow condition. In order to obtain the directional information in the eye stimuli, one must search for, and focus on the pupil.

This would require the viewer to adopt a narrow attentional zoom setting. This would allow attention to be focused or "zoomed in" on the central part of the image, enabling the viewer to locate the task-relevant information. A narrow zoom setting also means that the location of the image on the screen may be processed to a lesser degree. This may explain why there is no congruency effect in the gaze or symbol trials. In contrast, the attentional zoom setting required to process the arrows can be much broader. As a result, the location of the arrows on the screen is much more likely to be processed, leading to the congruency effect.

Experiment 3

Experiment 3 directly compared responses to the gaze and symbol stimuli using a within-subjects design. If similar RTs are produced in the two conditions, this will support the notion that the different pattern of data between the gaze and arrow stimuli in Experiment 1 was not due to the gaze stimuli being biologically important.

Method

Experiment 3 was the same as Experiments 1 and 2 with the exception of the stimuli used. Experiment 3 used the gaze stimuli from Experiment 1 and the symbol stimuli from Experiment 2. A 2 x 2 repeated-measures design was used with the two factors being type of stimulus (gaze vs. symbol) and congruency (congruent vs. incongruent). As in the previous experiments, stimulus type was manipulated between sessions, but congruency was varied within a block. Forty new participants (M = 21.5 years, SD = 6.2) took part in the study.

Results and Discussion

To be consistent with the previous experiments, we again used AdjRTs. Mean RTs and error are in Table A2 of the Appendix. One participant's data were removed from analyses due to computer malfunction.

Repeated-measures ANOVA was conducted on the AdjRTs (Figure 5). A significant effect of stimuli type was found, $F(1, 38) = 7.4$, $MSe = 2245$, $p = .01$, $\eta_p^2 = 0.16$. RTs were faster when participants were presented with gaze stimuli (592 ms) than when presented with symbol stimuli (613 ms). The main effect of congruency, $F(1, 38) = 0.2$, $MSe = 203$, $p = .66$, $\eta_p^2 = 0.01$, and the interaction between congruency and stimulus type, $F(1, 38) = 0.67$, $MSe = 653$, $p = .42$, $\eta_p^2 = 0.02$, were not reliable, $F < 1$ in both instances, indicating no difference in the congruency effect between gaze and symbols.

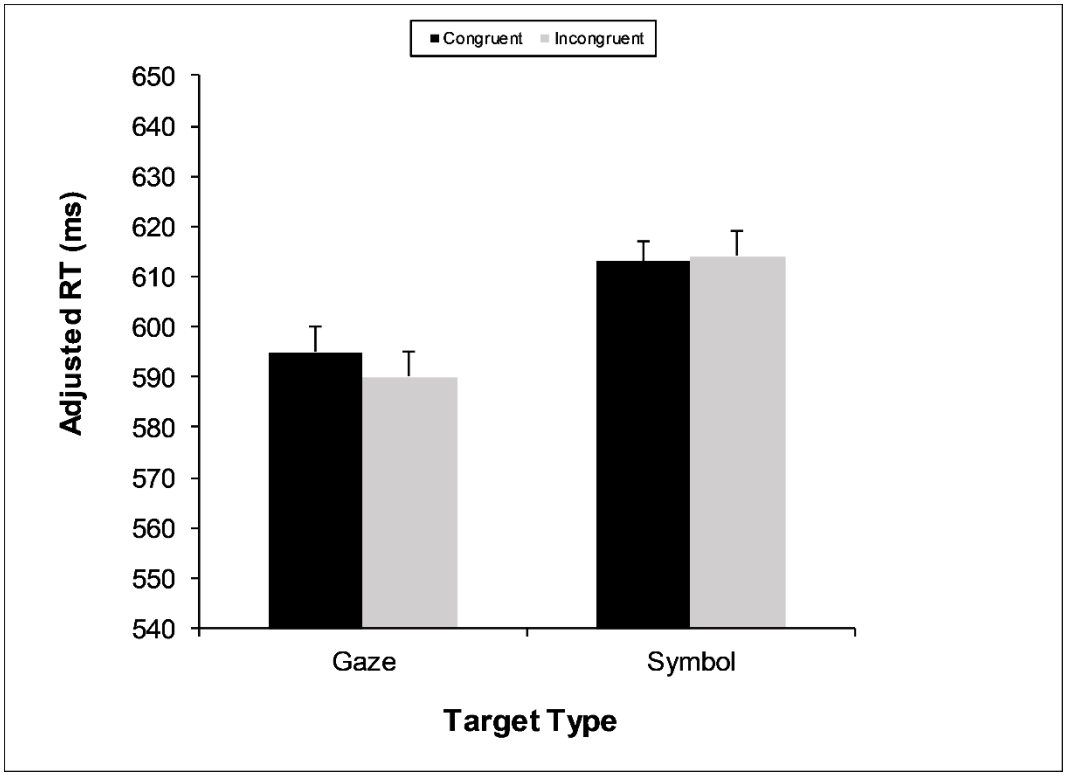


Figure 5. *Results from Experiment 3. Mean AdjRTs in milliseconds for each target type in each congruency condition. The error bars show the within-subjects standard error of the mean.*

Although there was no evidence that the gaze stimuli differed from the symbol stimuli in terms of the congruency effect, it is possible that the perception of one type of stimuli affected the other due to the fact that participants view the two stimuli types in separate sessions. To investigate if this could be the case, we examined the data from the first block

only. A 2 x 2 mixed-ANOVA with stimulus type as a between-subjects factor and congruency as a within-subjects factor revealed that there was no main effect of stimuli type, $F(1, 37) = 2.47$, $MSe = 7570$, $p = .12$, $\eta_p^2 = 0.06$. There was also no evidence of interaction, $F(1, 37) = 2.96$, $MSe = 924$, $p = .09$, $\eta_p^2 = 0.07$. These results indicate that it is unlikely that the lack of congruency effect in the gaze and symbol conditions was a result of any kind of practice effect or the experience of having previously viewed the other stimuli type.

An important finding in Experiment 3 was the absence of a congruency effect in the symbol and gaze conditions. This is consistent with the findings of Experiment 1, in which no congruency effect was found in the gaze condition, and in Experiment 2, in which no congruency effect was found in the symbol condition. The results of Experiment 3 show similar responses between the two stimuli types. This is important because of the nature of the differences between the stimuli types. Eye gaze has social significance and biological relevance to us, whereas infinity-like symbols are used in mathematics and are not socially significant or biologically relevant to us. The similarities between response patterns provide further support for the idea that it is the physical properties of a stimulus rather than the nature of the stimulus that influenced the congruency effect found in the present study.

The results of Experiment 3 also showed longer response latencies when participants were shown the symbol stimuli rather than the gaze stimuli. This could be due to the fact that in our everyday lives we are very familiar with the way that eyes indicate direction. We are well practiced at recognising and responding to directional information produced by eye gaze. Symbols, on the other hand, are different. We are not practiced at responding to directional information held within infinity symbols, and we are not well familiarised with the symbols that were specific to these experiments.

It is also possible that the strategies that participants use to respond may have an effect on the results. Recall that in the experiment, the symbol and gaze stimuli were

presented in different blocks. When different types of stimuli are blocked, participants are able to use different strategies to respond to the stimuli. To check whether the pattern of data in Experiment 3 might be caused by response strategies, we mixed the two types of stimuli within a block in Experiment 4. If the main effect of stimulus type disappeared, this would provide evidence that response strategies played a role in the results of Experiment 3.

Experiment 4

In order to prevent participants from using different response strategies between the gaze and symbol stimuli, the two types of trials were randomly mixed within a block. This takes away the ability to predict which type of trial will come next. If the use of different response strategies is what is causing the difference in reaction times in Experiment 3, mixing these trials within a block should result in little difference in reaction times between the two target types.

In Experiment 4, we also manipulated stimulus presentation duration to assess whether the results of Experiment 3 only applied to situations allowing saccade-related overt orientation. The targets were presented for either 200 ms or until response as in Experiments 1 to 3. Previous research has shown that completing an eye movement within 200 ms can be difficult (Mayfrank, Kimmig, & Fischer, 1987). If the same results were obtained in the two duration conditions, this would indicate that the results of Experiment 3 do not depend on overt shifts of attention.

Method

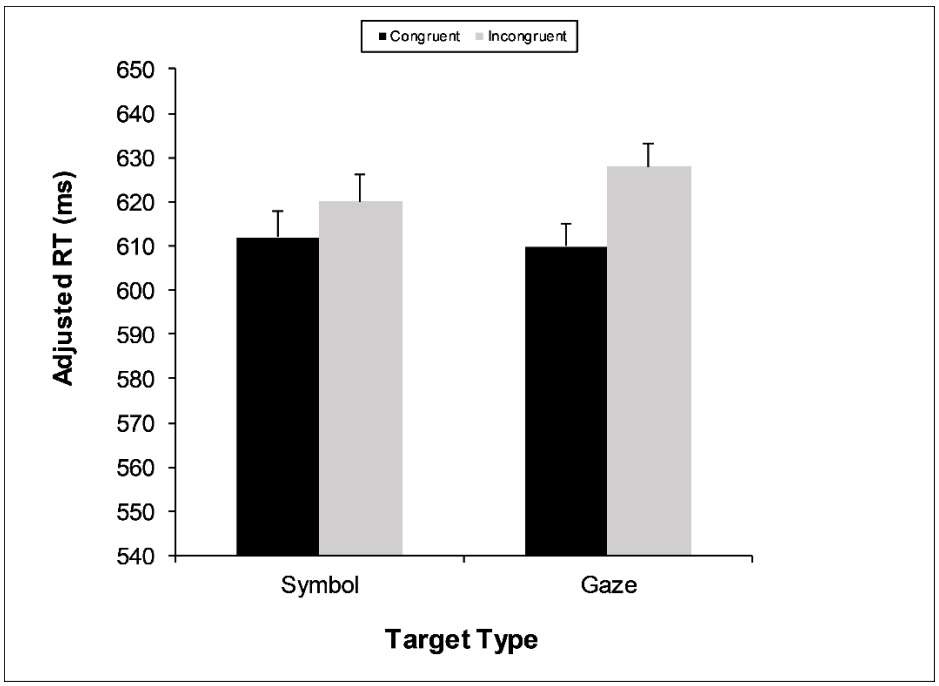
Experiment 4 used the same method as Experiment 3 except for the following differences. Gaze and symbol trials were mixed within a block instead of being presented in separate blocks. The duration in which the target was displayed varied across trials. Half of the trials used the same display duration as in the previous experiment (targets stayed on

screen until response or for 2000 ms, whichever came first). The other half of the trials used a presentation duration of 200 ms before offset. Both types of trials were presented randomly within a block.

Results and Discussion

To be consistent with previous experiments, the data was treated in the same way for Experiment 4. Three participants' data were excluded due to high error rates. The results are shown in Figures 7A and 7B. A 2 x 2 x 2 repeated-measures ANOVA on the AdjRTs showed that responses were faster when the duration was long (586 ms) compared to when the duration was short (617 ms), $F(1, 36) = 36.29$, $MSe = 1989$, $p < .001$, $\eta p^2 = 0.50$. However, duration did not interact with any other factors. Importantly, the main effect of stimuli type was no longer present, $F(1, 36) = 0.02$, $MSe = 1596$, $p = .88$, $\eta p^2 = 0$. Consistent with Experiment 3, no interaction between stimuli type and congruency was found, $F(1, 36) = 0.72$, $MSe = 782$, $p = .40$, $\eta p^2 = 0.02$. No other effects were found. See Tables A3-A4 in the Appendix for all effects.

(A)



(B)

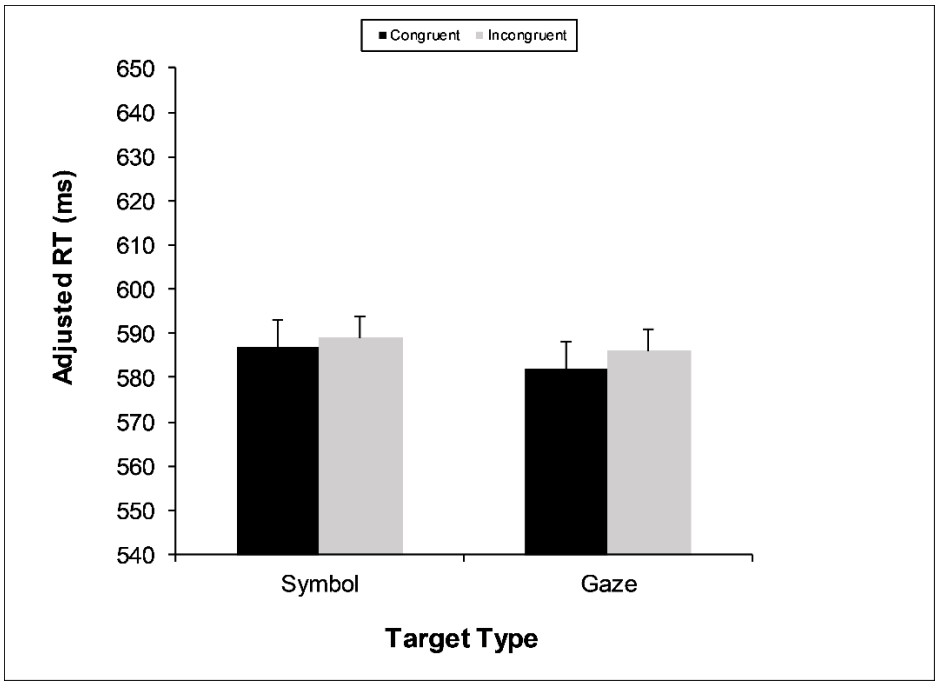


Figure 7. *Results from Experiment 4. (A) The short duration condition. (B) The long duration condition. The error bars show the within-subjects standard errors of the mean.*

In Experiment 4 there was an absence of the main effect of stimuli type. This supports the idea that the results of Experiment 3 are likely due to participants using different response strategies. Experiment 4 made it difficult to use different response strategies as the target types were mixed within a block. This likely forced the participants to use the same response strategy for both the gaze and symbol trials. Consequently, the effect of stimuli type was no longer present. There was also an absence of an interaction between stimuli type and congruency, which is again consistent with the results of Experiment 3.

Participants were faster when the image was presented for a longer duration. When the image stayed on the screen for a longer time, perceiving the direction indicated by targets would be straightforward, enabling a fast response. It is possible that when the duration was shorter, participants might have to think for a moment about what they had seen before they could answer. This may explain why response times were longer when the display duration was shorter.

Despite the main effect of duration, duration did not interact with any other factors. The latter result indicates that whilst the mechanisms behind overt and covert attention differ (Beauchamp, Petit, Ellmore, Ingeholm, & Haxby, 2001; Kulke et al., 2016), they do not appear to be influencing the effect of target type on processing efficiency. Thus, in the present paradigm, the attentional system does not appear to treat gaze differently from non-biologically relevant stimuli such as infinity-like symbols or arrows. This again provides support for the idea that the differences in response patterns between the target types reported in Marotta et al. (2018) were likely caused by the differences in the physical properties of the stimuli used in their study rather than the nature of the stimuli.

General Discussion

This study compares stimuli that are biologically relevant to us to stimuli with no biological relevance to us in an effort to determine if the results from Marotta et al. (2018) were caused primarily by differences in the nature of stimuli (gaze vs. arrow) or by differences in their physical properties. In Experiment 1, we used the same stimuli as those used in Marotta et al. The results produced data patterns that were largely similar to those reported by Marotta et al. (2018). Participants were faster when responding to the arrow targets than the gaze targets. In addition, a significant congruency effect was found in the arrow condition. However, unlike the results produced by the original study where there was a reverse congruency effect in the gaze condition, we did not find any reliable congruency effect. In Experiment 2, we replaced the gaze stimuli with similarly looking stimuli made of infinity symbols. The results showed that participants continued to respond faster in the arrow trials compared to the infinity symbol trials, and a significant congruency effect was again found in the arrow trials but not in the infinity symbol trials. These results indicate that the different pattern of data between the arrow and gaze trials in Experiment 1 was unlikely to be caused by a difference in the nature of the two types of stimuli.

In Experiments 3 and 4 we compared the gaze and symbol stimuli directly. In Experiment 3 there was no effect of congruency in either the eye-gaze condition or the symbol condition. This is important since the two types of stimuli differ in nature (biologically relevant vs. not relevant). There was also no reliable interaction between stimulus type and congruency despite the main effect of stimulus type, which was likely due to a between-block design. In Experiment 4, a within-block design was used, and the main effect of stimuli type found in the previous experiments was eliminated. Once again, the interaction between stimulus type and congruency continued was not found. These results suggest that the main factor causing the differences in response patterns is not social

significance. If gaze is special in some way, we should see participants responding to the gaze stimuli differently from responding to the infinity symbols.

Marotta et al. (2018) found a reverse congruency effect that we did not find in the eye-gaze condition. They suggested that this reverse congruency may be due to the fact that eyes may indicate more than just direction. When the eyes are presented, for example, on the left and are looking to the right (an example of an incongruent trial), this gives the appearance of the eyes making eye-contact with the participant. A number of studies that are discussed earlier (Baron-Cohen et al., 1997; Macrae et al., 2002; Senju & Johnson, 2009) show evidence that we respond faster when eye-contact is made and it is suggested by Marotta et al. that this could possibly be what is causing the reverse congruency affect here. However, there is evidence that the eye-contact effect may not occur when the angle of the head is not discernible (Conty et al., 2006). Given that the stimuli used by Marotta et al. consisted of human eyes without any visual cues to indicate the angle of the head, it is unclear what caused the reverse congruency effect in Marotta et al.

Marotta et al. (2018) also suggested that alternatively, it may be possible that Baron-Cohen et al.'s (1997) "mentalizing" theory applies here. In the incongruent condition participants may be engaging in joint encoding with the stimulus. To put it simply, eyes presented on the right but looking to the left may be seen as having the intention to continue an action at the left-hand location and thus it would be advantageous to orient one's attention to that location. Marotta et al. suggested that this ability to respond quickly to these types of signals from others may explain why participants are able to respond faster in the incongruent condition. Although this explanation is possible, it is unclear how reliable the reverse congruency effect is, as we did not find the same effect in any of the four experiments in the present study, even though Experiment 1 in our study was modelled very closely on the experiment reported in Marotta et al.'s original study.

Marotta et al. (2018) also mentioned the concept of domain-general processing and how they do not think their results fit with this idea. They found a typical spatial Stroop effect in the arrow condition and a reverse spatial Stroop effect in the eye-gaze condition. They reason that the same attentional mechanism would unlikely produce opposing congruency effects within the same task and that this difference would not be in line with the concept of domain-general processing. Our results did not find any opposing congruency effects and we propose that the different patterns of response between the gaze and arrow conditions in Marotta et al. were most likely due to physical differences between the different stimuli types requiring different amounts of attention rather than as a result of separate mechanisms being used due to the nature of the two types of stimuli.

What might cause the absence of the congruency effect in the gaze or the infinity symbols condition in our study? In previous literature, visual attention has been compared to a zoom lens (Eriksen & Rohrbaugh, 1970; Eriksen & Hoffman, 1972; Eriksen & St. James, 1986). When attention is "zoomed out", all else being equal, the distribution of attentional resources is spread over a large region of the visual field making visual processing slower or less accurate. As attention is "zoomed in" there is a greater concentration of resources at a smaller area making visual processing more efficient. The extent of attentional zoom may have played a role in the present study. The directions indicated by the arrows were easier to discriminate than those indicated by the eye-gaze stimuli or the infinity symbols. This is evidenced by faster RTs in the arrow condition in both Marotta et al.'s (2018) experiment and the present study. Since the task in the arrow condition was easier, the attentional zoom setting used by the participants was likely to be broader. It is also likely that one's default attentional zoom setting is relatively broad when the task does not require attention to "zoom in". In contrast to the arrow condition, perceiving the direction of the eye-gaze was not very easy. The image was more complex and the pupil, which was necessary for participants to

obtain the directional information, was small and surrounded by other colours. This would likely require participants to adopt a narrower zoom setting as the task demand was quite high. This could explain why participants were faster at responding to arrows compared to eye-gaze or infinity symbol stimuli.

With regard to the congruency effect, participants were faster at responding to the arrows in the congruent condition rather than the incongruent condition, but a similar congruency effect was not found in the eye-gaze or the infinity symbol condition. It could be that in the arrow condition, the use of a wider zoom setting also allowed participants to take in the surrounding spatial information such as the location of the arrows relative to the fixation, resulting in slowing down in the incongruent condition. A narrow zoom setting in the eye-gaze or infinity symbol conditions would make it easier for participants to ignore conflicting spatial information, leading to little difference between the congruent and incongruent trials in these conditions. Due to the fact that eye-gaze and infinity symbols produced similar results, it is unlikely that eye-gaze is special due to its biological relevance since participants responded similarly to infinity symbols. It is worth noting that these two types of stimuli were similar physically but different in nature.

Although there is no evidence in the present study that eye-gaze is special because of its biological relevance, we recognise that gaze may be special in other contexts. In our day-to-day lives gaze is good at attracting our attention. If someone's gaze is averted, often your instinct is to follow the person's gaze with your own. This ability for another's gaze to attract your own gaze and attention is part of reflexive orienting. Friesen and Kingstone (1998) found that gaze shifts could produce shifts of attention despite the fact that participants were told that gaze direction was non-predictive and completely uninformative. Related findings have also been reported by Driver et al. (1999), Langton and Bruce (1999), and Friesen, et al. (2004).

It is also widely known that eye contact is a large part of social interaction even in the very early life stages. Farroni, Massaccesi, Pividori, and Johnson (2004) found that new-born babies had a preference for human faces that made direct eye contact when compared with faces where the eyes were averted. They also found that new-born babies could distinguish between faces that showed direct gaze and averted gaze. New-borns also responded to the eye direction of schematic faces and were quicker to make saccades when targets at the peripheral were cued by the direction of the eyes shown on the schematic face. This only occurred when movement was seen (the motion of the pupils). This shows that from birth we may show signs of gaze following.

D'Entremont, Hains and Muir (1997) found that 3 to 6-month-old children displayed behaviour that they suggest could be the beginnings of children engaging in joint attention. Hood, Willen and Driver (1998) found that children as young as 3 months old were able to discriminate the direction of perceived gaze. It was also found that perception of another's gaze led to shifts in their own attention to the same location. This further supports that we may be born with some kind of preference for eye-gaze. It should be noted however that in these cases gaze was accompanied by a turn of the head in the corresponding direction.

There is also physiological data that supports the idea that gaze may be special. In a study using macaque monkeys, Perret et al. (1985) found that when monkeys viewed eyes through a small slit, there were cells in the superior temporal sulcus (STS) that showed excitatory responses to gaze. Further research by Perret, Hietananen, Oram, Benson, and Rolls (1992) also showed that some neurons had a preference for straight gaze and others for averted gaze. Campbell, Heywood, Cowey, Regard, and Landis (1990) investigated the impact that lesions in the STS region had on monkeys and found that there was a disruption in gaze discrimination in lesioned monkeys.

However, despite the above studies in support of gaze perception being special, there is also evidence that in different situations, gaze is not special, and is perhaps processed by the same mechanisms as stimuli that are not biologically relevant to us. Tipples (2002) demonstrated that both gaze and arrow cues could trigger reflexive orienting. This suggests that gaze may not be special in this context and contradicts earlier claims that uninformative symbolic cues cannot trigger reflexive or automatic orienting. Tipples (2008) found that when gaze and arrow cues were compared, they produced similar voluntary and involuntary orienting effects. They found that individual differences in voluntary control were contributing to involuntary orienting effects rather than the nature of the stimuli. Again, this suggests that in some environments, responses to gaze are no different from responses to other non-gaze stimuli. This is consistent with the proposal that gaze and arrows may share a domain-general process rather than being a part of separate, domain-specific processes (Birmingham & Kingstone, 2009; Santiesteban et al., 2014;).

Brignani, Guzzon, Marzi, and Miniussi (2009) found that eye-gaze and arrows induced the same attentional effects and they used an event-related potential (ERP) experiment to determine whether these effects were created by distinct neural attentional mechanisms or by the same mechanism. Similar ERP responses and topography were found, suggesting that even though eye-gaze and arrows appear to produce early orienting of attention, it is more likely an exogenous process. The researchers attributed the results to an overlearned association between certain stimuli and the directional information that they communicate. This again provides support for the idea that gaze is not special because of its social significance and that gaze may be processed with the same mechanism as other non-biological stimuli, at least in certain contexts.

In summary, although previous research has shown that eye-gaze can be special in some contexts, in the present study, we found no evidence that the processing of gaze differs

from the processing of non-gaze stimuli such as arrows or infinity symbols. We attribute the different patterns of results reported in Marotta et al. (2018) to the physical differences between the eye-gaze stimuli and the arrow stimuli used in their study. Specifically, the two types of stimuli require different attentional zoom settings for participants to process the directional information held within the stimuli, and this resulted in differences in response patterns. As we showed in our study, when we changed the stimuli to look more physically alike, we saw little differences in response patterns suggesting that gaze is not special because of its biological relevance. Our results underscore the importance of controlling differences between stimuli when studying gaze processing. They also suggest that some previously reported findings in support of a special role of gaze in attracting attention may be caused by factors other than the nature of the stimuli being of biological significance.

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Notes

1. Stimuli were kindly provided by Andrea Marotta and were scaled to fit a screen resolution of 1680 x 1050 pixels as the original images overlapped the fixation cross on our monitors. All measurements given in the text reflect this change.
2. A survey was conducted to ensure symbol stimuli were not viewed as eye-like. Eleven people were asked what they thought the symbols were. The answers were: hourglass (6), tadpoles (1), pebbles (1), not much of anything (1), random geometric shapes (1), and power plug (1).

Appendix

Table A1. *Mean reaction times (in milliseconds) and percentages of incorrect responses (%IR) for Experiment 2 as a function of stimulus type and congruency.*

	Symbol				Arrow			
Trial Type	RT	SD	%IR	SD	RT	SD	%IR	SD
Congruent	619	73	2.6	3.2	539	75	2.4	5.2
Incongruent	622	82	3.7	4.7	546	79	5.2	5.3

SD = Between-subjects standard deviation.

Table A2. *Mean reaction times (in milliseconds) and percentages of incorrect responses (%IR) for Experiment 3 as a function of stimulus type and congruency.*

	Gaze				Symbol			
Trial Type	RT	SD	%IR	SD	RT	SD	%IR	SD
Congruent	581	63	2.3	3.0	599	59	2.3	2.7
Incongruent	572	64	3.0	3.2	593	67	3.3	3.4

SD = Between-subjects standard deviation.

Table A3. *Mean reaction times (in milliseconds) and percentages of incorrect responses (%IR) for Experiment 4 as a function of stimulus type, congruency, and target display duration .*

	Gaze				Symbol			
Trial Type	RT	SD	%IR	SD	RT	SD	%IR	SD
Congruent Short	576	68	5.4	5.3	577	69	5.6	5.4
Incongruent Short	575	77	8.1	5.5	579	75	6.4	5.2
Congruent Long	549	60	5.5	6.5	556	63	5.1	5.8
Incongruent Long	549	66	6.1	5.6	553	61	5.8	5.2

SD = Between-subjects standard deviation.

Table A4. *Repeated Measures ANOVA for Mean AdjRTs for Experiment 4.*

Effect	SS	df	F	p	partial eta-squared
DUR	72166	1	36.285	<.001	0.50
STIMTYPE	35	1	0.022	0.88	<0.01
CONGRUENCY	4603	1	1.041	0.31	0.03
DUR*STIMTYPE	899	1	1.082	0.31	0.03
DUR*CONG	1899	1	2.399	0.13	0.06
STIMTYPE*CONG	559	1	.0715	0.40	0.02
DUR*STIMTYPE*CONG	299	1	0.595	0.45	0.02